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Design of control circuit of grid-connected photovoltaic system based on SPMC75F2413A

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Abstract

This paper discusses the experimental design of a grid-connected photovoltaic system based on 16-bit Microprocessor (MCU) SPMC75F2413A. In this paper, the SPMC75F2413A as the main topology control the main circuit of the Single-phase bridge type inverter. The system can track the maximum power point by detecting PV(photovoltaic) voltage, current and grid-connected output voltage and current, and simultaneously can track the frequency and phase by the software phase locked loop. The testing results of the grid-connected photovoltaic system shows that the grid-connected voltage and network voltage are synchronous, and the system is feasible and practical.

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Keywords : grid-connected photovoltaic; voltage source type inverter; maximum power point track; SPMC75F2413A

Introduction

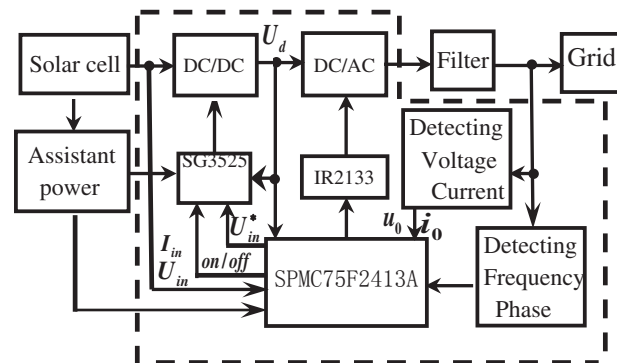
With the reduction of the non-renewable energy, power shortages and environmental pollution aggravated and so on, the solar energy as the cleanest of alternate energy resources plays an important role in the protection of the environment. Now the lower power stand-alone PV system gradually transfers into the grid-connected PV system. The grid-connected PV technology has become an important aspect with the establishment of a large scale PV power station [1].

In this paper, based on the basic principles and working structure, researches and implements the low power grid-connected PV system that is controlled by a 16-bit microcontroller SPMC75F2413A. The low power grid-connected PV system is researched and implemented based on a 16-bit microcontroller SPMC75F2413A, then combined the drive chip SG3525 and IR2133 to control the inverter of the main electric circuit system. The frequency, phase of the power grid-connect, and maximum power point tracking is precisely controlled by a double close-loop feedback control (voltage loop and current loop) system, so a stable sinusoidal AC 220V/50Hz voltage will be supply with the grid.

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2. Structure and Principles of PV system

The theory graphics of the photovoltaic system can be seen below in figure 1.



The theory graphics of the Photovoltaic system

The whole system includes the solar cells, and the network controller, the filter and load. The network controller is the center of this system, which consists of several parts: DC / DC converter, DC / AC inverter, driver circuit, control circuit and detection circuit.

3. Design of the Main Circuits and principle

The Main Circuits of photovoltaic system can be seen in figure 2. The photovoltaic system adopts two-stage approach, a DC/DC stage followed by a DC/AC stage [2].

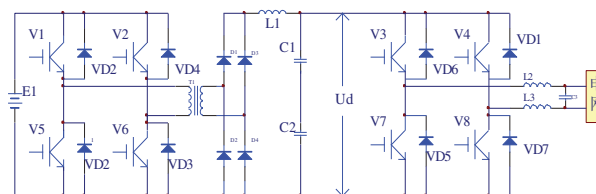
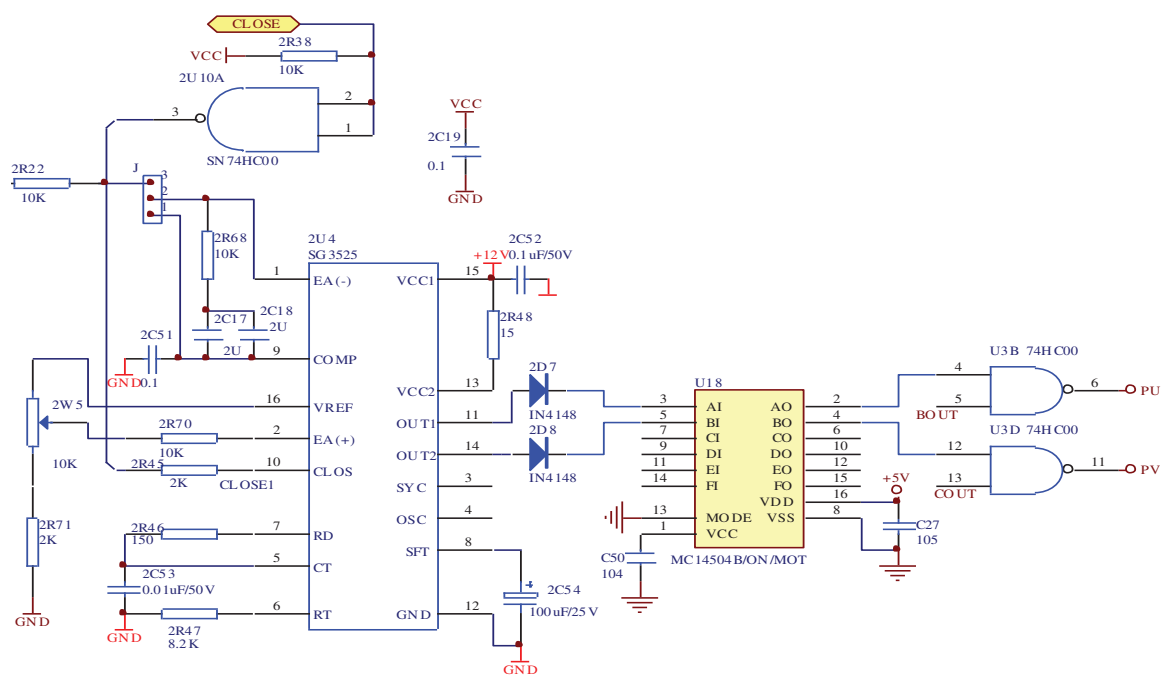
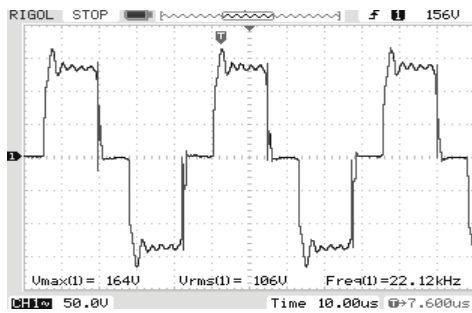


Figure 1. The critical theory graphics of the PV system

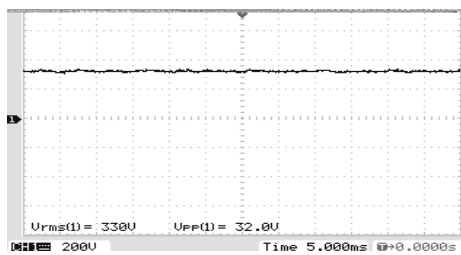
The sine pulse width modulating signals would be produced by the SG3525. CPU sends out 22KHz trigger pulses to flow through H-bridge that consists of four IGBT. Low-voltage DC can be transformed to high frequency AC which is raised voltage with high-frequency transformer, then the high frequency AC will be transferred to high voltage DC above 300V by fast rectifier diode. The principle diagram of the DC-DC driving circuit is shown in Figure 3.



The output voltage of DC-DC inverter is 22.12KHz AC whose amplitude value is 164V. The waveform is shown in Figure 4, we can get the high-voltage DC about 330V by boosting voltage with transformer and then converting voltage with rectifier filter, as shown in Fig 5.



inverter voltage wavThe e of DC-DC



The DC voltage wave after filtered

DC/AC inverter is one of the key assembly units of the PV system, whose function is inverting the 330V high voltage DC into AC by full bridge converter, 220V/50Hz AC voltage is transmitted to the grid. The whole control system of DC/AC inverter uses single-chip center control unit by a 16-bit microcontroller SPMC75F2413A after filtering. The DC-DC driving circuit is shown in Figure 6.

IR2133 is a high performance driving chip, which was pulsed under the input of PWM at work. SPMC75F2413A with 16-bit single chip microcomputer provide input pulse for IR2133. The input signals of IR2133 are compatible with the output signals of 5V CMOS or LS TTL circuit, the output voltage peak at 20V so that it's driver capability has been notably enhanced [3]. It can attain the purpose of driving IGBT accurately and correctly. The input control and logic circuit in chip provides dead-zero time to the high-end and low-end at the same bridge-arm to prevent the power sources from being turned on simultaneously on the course of commutations of switches, so the driving pulse has a good stability and reliability.

4. Design and the working principle of Photovoltaic Control System

The Control System diagram of Photovoltaic grid-connected are marked with dotted lines in figure 1.

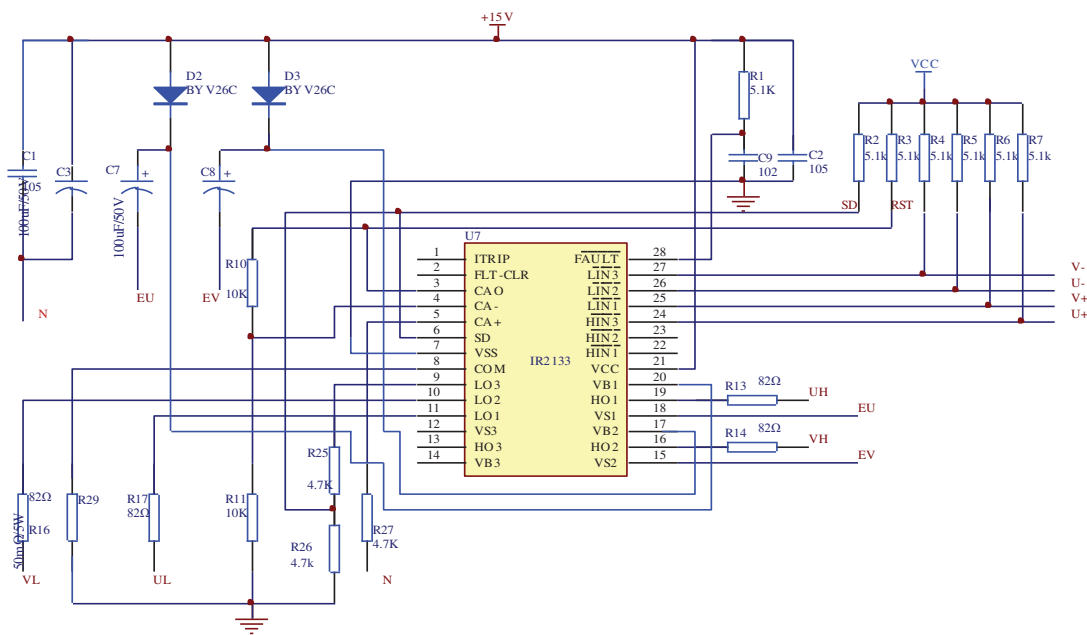
The control circuit of Auxiliary Power Supply

The Auxiliary Power furnishes the control circuits of the whole PV systems with electricity, the supply of the auxiliary power, too, comes from the Photocell board.

a. *The DC-DC control circuit*

b. *DC-DC converter composes a closed loop by making use of sine pulse width modulating signals produced by the SG3525, whose start and stop are controlled by CPU. The output singles of SG3525 are two 22KHz driving powers, which fires four IGBT of H-bridge. CPU draws a comparison between U_d (identified DC output voltage) and U_{in} (command voltage). Then CPU controls the pulse-width of the SG3525 Output driving signal by using PI regulator which adjusted error voltage. That is to say, The control pulse will be in narrow when U_d is big, on the contrary, it will become wider. So the voltage closed loop control is realized that we can gain constant output voltage [4].*

c.



d.

e. The principle diagram of the DC-AC driving circuit

f.

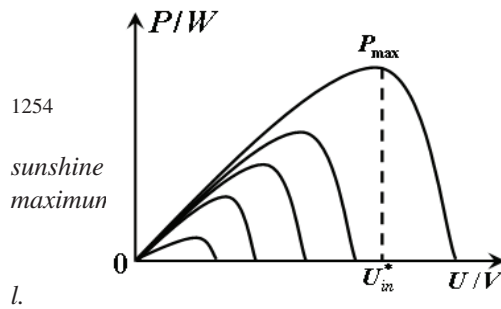
g. The DC-DC control circuit

h. DC/AC inverter uses single-chip center control unit by a 16-bit microcontroller SPMC75F2413A. In this system, the output voltage of the photocell board is between 50V to 80V DC which is changed into about 330V DC, and then is converted 330V DC into 220V/50Hz AC voltage. The principle diagram of the DC-AC driving circuit is shown in figure 6.

i.

j. The realized of the maximum power point tracking control

k. The output characteristics of solar cell is changeable with Variation of temperature and solar radiation intensity, namely, we can gain a family of output characteristic curve in different temperature or solar radiation intensity, as shown in figure 7. The solar cell can work randomly on a certain output characteristic curve in different or temperature and solar radiation intensity, in addition, different in operating point and actual output power. That is to say, with the change in temperature and solar radiation intensity, the maxim power and maximum power point voltage of the solar cell will change [5]. So to make full use of energy source, the working point of the solar cell must be the maximum power point and it's vicinity. It is not hard to see from the $P-U$ curve that, for the maximum output power of photovoltaic cell array under given conditions of a certain environment temperature and



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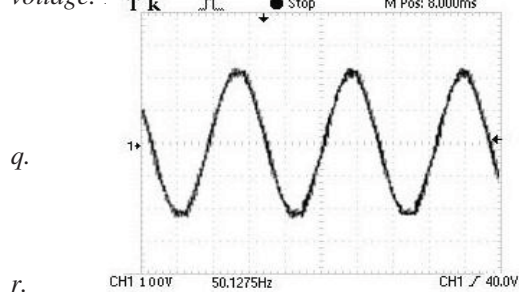
domain, we may control the input voltage of solar cell is on the

m. The Photovoltaic output characteristic curve

n. The selection of the maximum power point voltage U_{in}^*

o. The value of the maximum power point voltage U_{in}^* can gain by heuristics. For example, at a certain hour, the output voltage and current of the solar cell are U_{in} and I_{in} respectively, the accurate value of power can be calculated by the formula: $P = U_{in} I_{in}$. At regular intervals, a slight increasing trend ΔU gives U_{in} to SG3525 through CPU. SG3525 controls output current of inverter by the way of for a given range of input voltages to control Pulse Width changing input voltage to, so as to control the output power of converter [6]. The output power of inverter should be equal to the power supply of the solar cell at the case of ignoring loss of inverter. At the same time, The output current of the solar cell is I_{in} , and calculates the output power $P' = (U_{in} + \Delta U) I_{in}$ of the photocell board. If $P' > P$, you can increase U_{in} , until find out the maximum power point voltage U_{in}^* . On the contrary, if $P' < P$, U_{in} should be reduced, the maximum power point voltage is U_{in}^* [7].

p. The frequency and phase of the grid voltage will be raise and fall occasionally, so the other main function of CPU is to detect the frequency and phase of the grid voltage, then tracking the frequency and phase of the grid voltage through the software PLL and tracking technique to make the frequency and phase of the inverter output voltage. The waveform of the grid voltage is shown in figure 8.



s. The output voltage waveform

t. 5. Detecting of the inverter output single

u. The output voltage and current of inverter is AC which must be changed into low voltage AC, then change the low voltage AC into DC by RMS value convert Chip, lastly change the low voltage AC into digital signal by A/D transform chip. The single chip microcomputer may control the output voltage and current by the closed loop control system that the system has a good stability and reliability.

6. Analysis of the experimental results

v. *We designed and simulated a set of photovoltaic grid-connected inverter, the solar cell is taken the place of 50~80V DC power source. The input voltage and current of the system is detected by a voltmeter and ammeter, the output voltage and current of the system is detected by power line harmonic analyzer. The result shows that the output current RMS is 0.9A, the output power is 200W, the conversion efficiency is 85.7%, and more the output voltage waveform is good. In summation, basic condition method is presented the results is well.*

7. Conclusion

The low-power grid inverter by the current control is used in this system. It has a power factor of near 1, a high-frequency transformer to achieve the function of transformation and insulation, the size of the apparatus is reduced. A novel control strategy is developed in which power variation of load is used instead of the power variation of PV array output to track the maximum power point of PV array. And TMPPT of PV array is realized by applying the variable step voltage disturbance control algorithm. The experimental result demonstrates that the shape of current wave is good, the grid-connect current is basically synchronous with the grid voltage, the power factor close to 1. The experimental results prove the feasibility and practicability of the system.

Acknowledgment

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